COST EFFECTIVE EVALUATION TECHNIQUES FOR FCC ATOMIZING NOZZLES

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INTRODUCTION

The improvement of gasoline yields and quality on FCC plants has been a must on the field of oil industry research and development over the last several years. The high inlet processing volumes make any improvement either in conversion or product quality result in very high levels of financial savings. There is an important relationship between the oil feeding quality and the oil-catalyst interaction which leads to such better yield and quality upgrade[2].
The complete uniform mixing of catalyst and oil has become a challenging target for FCC plant engineers and designers around the world. Besides the usage of heavier input oil makes such a mixing even more important. The oil-catalyst contact, vaporisation and residence times in the riser environment are all involved with inlet oil spray pattern. Some of the most important figures on feeding quality such as the droplet diameter, mass flow distribution on spray and momentum depend on the FCC atomisation nozzle. This paper discusses some on plant, cost-effective evaluation techniques, which may be applied by FCC plant engineers in order to choose a good feeding tip for their needs. High-speed photography, mass distribution measurements and other simple but effective evaluation procedures are discussed. Also a nozzle case study is shown, whose evaluation was carried out by such a set of techniques under several conditions.

FCC FEEDING NOZZLES

There are many commercial feeding nozzles types available on FCC technology world-wide. However about a dozen of such a models have been mostly used on plants lately. Some devices have registered marks and they are protected under patents.
The most used nozzle atomizer type is the twin-fluid atomizer. Those devices use a high velocity atomizing fluid, which impinges on a liquid traverse flow. The high relative velocity between the two fluids causes a very rapid deformation of the liquid film, the sheet break up, the formation of ligaments, drops and droplets.
In order to select a good tip for any specific need a FCC engineer may carry out an evaluation plan. The feeding oil physical and chemical properties, the atomizing steam availability, the pumping power and other operating conditions must be considered.
An effective evaluation plan must focus on the main known features of a good tip. As a matter of fact a good nozzle must fulfil a set of features as follows: Small droplet diameter under a narrow distribution[3]; uniform flow rate on spray; symmetrical flat shaped spray; stability; easy manufacturing and maintenance; life-span; turndown and performance.

EVALUATION PLAN

A challenging target in testing FCC nozzles on test rigs is the safe scale up and down process and the usage of test fluids instead of oil and steam. The usage of actual fluids on test rigs is difficult and even dangerous, due to the hazardous oil properties. Besides the test cost may increase considerable so a good choice is to replace oil by water and steam by compressed air.
Another well-used method is the tip scale up and down process to avoid the high mass flow rates used by the full-scale nozzle. Both methods may be used under strict theory rules otherwise the results from test rig fail. Above all there are some important

parameters and dimensionless numbers must be checked.

	Liquid	Gas
Density (ρ_L)	ρ_L	ρ_G
Viscosity(ν)	ν_L	ν_G
Surface tension(σ)	σ	
Relative velocity ($U_r=U_G-U_L$)	U_L	U_G
Reynolds Number (Re)	$R_e = \rho_L.U_L.d_0.\nu^{-1}$	
Weber Number (We)	$W_e = \rho_L U_r^2.d_0\sigma^{-1}$	
Initial jet diameter d_0		

On twin fluid atomizer theory the most important parameter is the Weber number(1). The feeding oil and atomizing steam under their operating conditions must have the above parameters as close as possible to the testing fluids, i.e. air and water at ambient temperature(4). Also tips scale up and down cannot properly succeed without such a set of parameters relationship. Furthermore scale down process using mass flow ratio by a factor over say, four times are not recommended as well. Fortunately FCC feedstock and steam have atomizing parameters quite similar to water and air at test rig conditions.

SOME EVALUATION TECHNIQUES

Some of the most effective measurement techniques for FCC atomizers are related to the oil spray pattern analysis. There are many quantitative and qualitative methods that may vary in cost, applicability and reliability. This paper discusses some cost effective "on plant" techniques that may be used by FCC plant engineers. They are: the nozzle test rig and apparatus; droplet sizing by high-speed photography; mass flow rate distribution and pressure profile measurement.

NOZZLE TEST RIG

A simple but effective test rig can be built up beside any utility facility on a FCC plant. All need utilities can be easily found such as water and compressed air. The rig flow capacity may be designed to test full-scale nozzles or scaled down model tips. Measurements of water and air flow rates can be easily achieved by conventional flow meters.

DROPLET SIZING

One of the most famous droplet sizing technique is the laser scattering. Some good overall advantages are:

-It is a non-intrusive method so the spray pattern is not disturbed (1).

-There is a fast, quantitative result such as the droplet distribution and mean diameters (SMD, the Sauter Mean Diameter, for instance).

Some few, but not less important disadvantages are:

-Scattering light devices are not suitable for dense sprays (1) (FCC nozzles produces typically dense sprays, even using a scale down model).

-The scattering light principle considers a droplet a globular shaped body. This is not true because the surrounding areas downstream the tip contains ligaments with typically non-globular shape.

-It demands investments on lab-like test rigs, equipment and high qualified technical staff.

HIGH-SPEED PHOTOGRAPHY

An alternative droplet sizing technique is the high-speed photography. It is not a quantitative method but it can give us a good idea about the spray pattern and droplet size (comparison). The high cost and difficult to use old spark flashes are not effective anymore. Nowadays a high-speed photographic system can be built up using only almost conventional devices (fig. 1). A simple set was successfully used to carry out tests on a group of FCC nozzles.

The camera does not need to have high speed shutter capabilities(5). As matter of fact even special high-speed shutters are enable to "stop" the spray image because the droplets velocity stream. The shutter is kept open while the trigger is pressed (on the "B" setting). The photo is taken in the darkness and the exposition time is the flash duration. An EG&G high-speed flash may produce a lightning as fast as 1/50,000 of a second. The speed film such as ISO 400 B&W is satisfactory (fig.2). Some conventional amateur electronic flash may be also used but the light is not powerful enough for quality photos.

MASS FLOW RATE DISTRIBUTION

A flat shaped spray may produce several mass flow rate patterns even with the same droplet mean diameter. Basically one of the oil/catalyst mixing goals is to inject the feedstock where the catalyst is and so a uniform mass flow distribution is required. Some commercial nozzles have good droplet mean diameter but poor mass flow distribution. Using a simple cell box device the mass flow distribution measurement can be carried out (fig 3). Also a distribution histogram of the collected water is shown. Many nozzles release much flow at the spray centre producing a non-ideal pattern(fig. 4).

STATIC PRESSURE DOWNSTREAM THE SPRAY

The pressure profile downstream the feeding nozzle used to be negligible in the early days of FCC feeding development. However low pressure zones downstream the atomization chamber may induce dangerous backward catalyst flow (inside Riser). The catalyst may impinge on the nozzle top at high velocity by means of backward stream. Sometimes the erosion is so hard that whatever the tip material is it may last only few hours. The pressure profile along the nozzle chamber and in the first feet downstream the top may vary under different operating conditions. A good nozzle should keep positive pressure on its turndown range. Using mercury U gauges such a pressure can be easily measured.

The pressure profile (example on fig.5) on tips is strongly dependent on geometry and pressure drops. Sometimes the chamber geometry, liquid injection angle, and mass flow liquid/gas ratio result in different pressure levels.

CASE STUDY

The set of techniques shown on this paper was successfully applied on a group of nine up to date FCC nozzles. The main target was to carry out a comparison study between the Petrobras UltraMist^R FCC nozzle and other commercial tips. All evaluation techniques discussed on this paper were successfully applied. Although the droplet sizing by high-speed photos results qualitative analysis, some good points and bad points were highlighted. Such a nozzle has got a good and uniform mass flow distribution, small droplet mean diameter and stability. Other commercial nozzles achieve good standard features as well. However there are some conflicting features they should be managed, such as droplet diameter and pressure profile.

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FIGURES

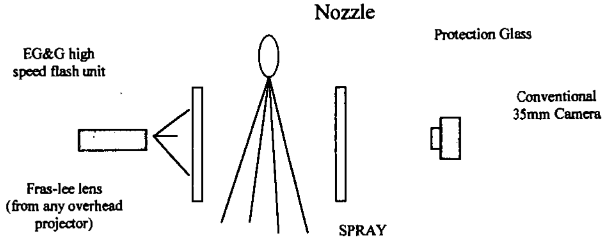

fig1. High-speed photography system-Schematic of apparatus

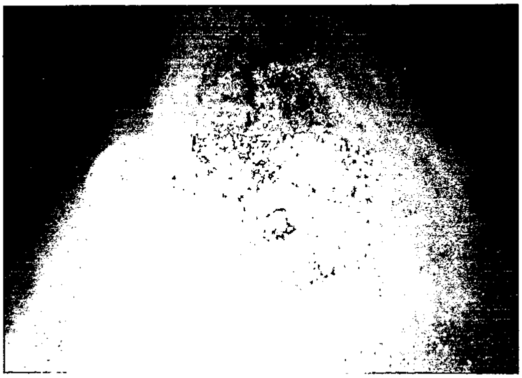

Fig.2 High speed photography (liquid flow rate=3230 Kg/h; air flow rate 100 Nm^3/h)

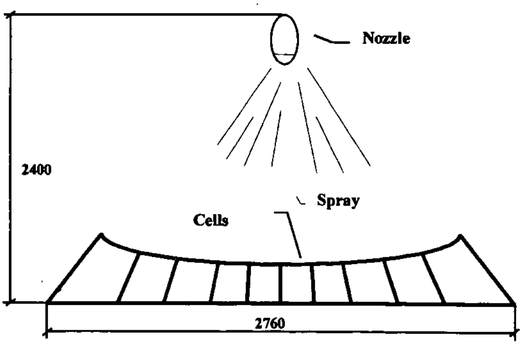

Fig.3 Cell box for flat spray flow distribution

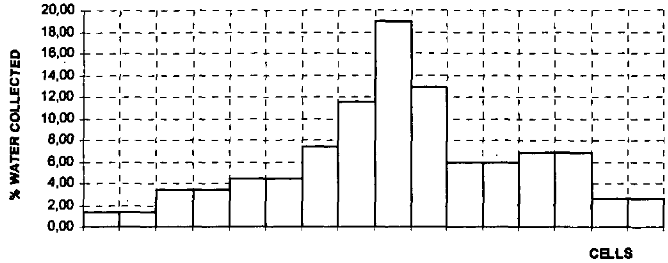

Fig.4 Mass flow rate on the spray-Histogram from the cell box

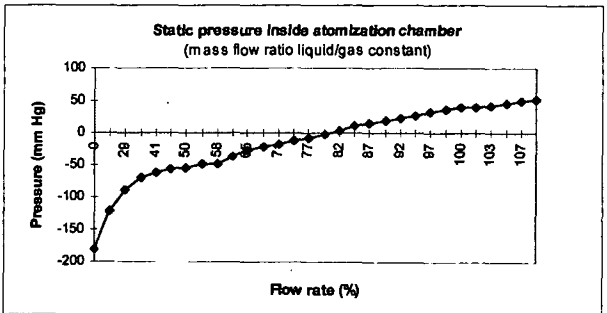

Fig.5. Pressure profile example